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MANTLE REDOX AND CONTRASTING TECTONIC PROVENANCE FOR OCEANIC AND CRATONIC MANTLE LITHOSPHERE

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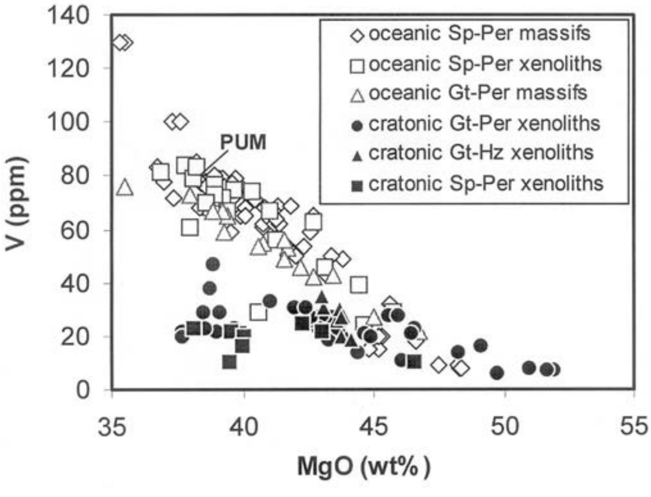
ABSTRACT

The compositional and mineralogical distinction between mantle lithosphere underlying old continental cratons and that beneath orogenic belts and ocean basins is well established (Boyd, 1989). The origin of many orogenic and oceanic peridotites as residues of partial melting at pressures less than 3 GPa in the spinel stability field is generally accepted. At such pressures, residues will be Ol-rich. In contrast, the highly depleted character, yet relatively Ol-poor (and Opx-rich) mineralogy recognized in xenoliths from many cratons require that such lithosphere is not a simple residue. Hypotheses for the formation of cratonic lithosphere were reviewed by Kelemen et al. (1998) who provided compelling evidence that most of the mantle lithosphere beneath cratons originates by partial melting in the spinel stability field, and that cratonic garnet peridotites with higher equilibration pressures have been tectonically transported to such depths. In this way, ‘on-craton’ lithosphere could be considered oceanic peridotite that has underplated to form Archean continents with the deep lithospheric keels. Nonetheless, of the hypotheses reviewed by Kelemen et al. (1998), none have convincingly tied the petrological origin of cratonic mantle lithosphere to a specific tectonic setting. It has been speculated that Opx-enrichment in cratonic mantle resulting from melt/rock reaction would proceed in a subduction zone, whereas the same feature would occur from high degrees of melting and related cumulate enrichment in the root of a mantle plume. Distinct chemical or mineralogical lines of evidence to link the mantle samples to these tectonic environments is so far lacking.

When interpreted in the light of a growing experimental data base for V partitioning (Canil, 1997; 1999) the systematics for V in cratonic and oceanic mantle help to further distinguish the conditions and the tectonic setting during melt depletion to form these two contrasting types of lithosphere. Examination of a data base of 200 spinel- and garnet peridotite analyses of on- and off-craton mantle xenoliths, and orogenic massifs from various settings show that the V abundances in mantle lithosphere lies along two distinct coherent trends (see Figure) when plotted against a depletion index such as wt% MgO. For a given degree of depletion, the V abundances of all cratonic peridotites, whether spinel- or garnet-bearing, are at lower levels than those of oceanic peridotites. The covariation of V with depletion for oceanic peridotites is explained (and modelled) as partial melting in the spinel stability field. Spinel has a D_V that is ~ 10 times higher than any other peridotite mineral at a given oxygen fugacity (f_{O_2}), and as a residual phase during partial melting at low/moderate pressures, and f_{O_2}’s near that of MORB generation (NNO- 2 or -3), will dominate the budget for V.

On the other hand, the spectrum of cratonic mantle compositions in the Figure requires either of the following: (1) Oceanic and cratonic peridotites represent residues from two completely different primitive mantle (PUM) sources; the source for cratonic mantle having a lower overall V abundance relative to PUM. (2) Unlike oceanic peridotites, cratonic peridotites are residues of melting at high pressures in the garnet stability field. Because D_V Gt is less than D_V Sp, less V is retained in the residue for a given degree of depletion. Quite possibly, neither garnet nor spinel are residual in the original melt depletion events related to cratonic peridotites, and both pyroxene and/or olivine, having low D_V are responsible for the smaller amount of V in the residues. (3) Cratonic mantle originates by depletion in the Sp stability field at low pressure where Sp is a residual phase, but at much higher f_{O_2} than oceanic peridotites related to MORB generation. The D_V for Sp is very f_{O_2} sensitive and varies almost an order of magnitude over the range of terrestrial f_{O_2}’s. The lower D_V Sp during melting at higher f_{O_2} (near NNO) would result in less V being retained in the residue.

Hypothesis (3) would constrain the formation of cratonic peridotites to a region of melt generation in the mantle of relatively high F_{O_2}, most likely related to subduction. The distinctly lower Ti/V ratios recognized in many arc-related tholeiites (Shervais, 1982) are a complimentary signature related to this process. The above hypotheses will be quantitatively described and explored using appropriate peridotite melting models and partition coefficients. If hypothesis (3) is accepted then partial melting in the Archean was more oxidized than hitherto realized, some form of subduction was operative, and the mantle lithosphere beneath Archean cratons is intimately related to the subduction process.



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